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An Extended Stochastic Petri Nets Modeling Method for Collaborative Workflow Process

Yang Yi

Dept. of Computer Engineering
Guangxi University of Technology
Liuzhou, 545006, P.R.China

Abstract

Workflow process modeling is important for BPR; some classic process modeling methods have many defects, such as weakness description ability, high modeling complex, and so on. In this paper, we explore an extended stochastic Petri Nets modeling method based on basic Petri Nets. This method can model concurrency collaborative workflow process under stochastic environment.

*Keywords:*petri net;workflow; process modeling;

1. Introduction

To make enterprises more competitive, design and develop some new organizational model will be helpful for enterprises' reasonable division and work process. From 1990s, a new fashion management idea—business process reengineering, took place and achieved some success in Northern America and Western Europe. Nowadays, spreading from Northern America and Western Europe, business process reengineering is favored the whole world and has extended its application to government. Process is the core of BPR and every enterprise is consisted of different kinds of processes. Traditional enterprises base their division of work on their functional departments, but do not familiar with process. In this situation, the implement of BPR will bring some conflicts to enterprises [1]. Experience shows that to reengineer the business process and at the same time to utilize resources reasonably, project-driven matrix organization and network organization fit the process-centered development.

Currently, there are many researches on the description of processes and tasks in organizations, such as Flow Chart, Situation Chart, Network Map, IDEF Chart, currency task logic[6],super media structure, event-driven process chain model, object-oriented method [7], Petri net [8,9]. Though these methods are effective in describing processes in some degree, there still exist some defects: (1)Basically they base their description on tasks and their corresponding relations, but have not related to resources (including people,

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machines and so on), rendering the system lacking the ability to deal with exceptions; (2)These models are not flexible enough. Most of these theories hardly refer to the change of environments in systems; (3)Poor description ability. Space explosion may occur when the process is complex. (4) It is not easy to depict dynamic work process, such as queuing process with different priority and stochastic distribution. Research reveals that Superior Petri Net and Extended Petri Net can solve these problems [10].

This paper attempts to model for the collaborative workflow process based on a kind of Extended Petri Net—Extended Stochastic Petri Nets.

2. Extended Stochastic Petri Net

2.1 Basic of stochastic Petri Net

Molly [11], Florin and Natkin[11] brought forward the theory to connect transitions with stochastic distribution delays. They assign the parameter process speed to every transition in the P/T net. This Petri net is stochastic Petri net (SPN). SPN has two formats: Molly model and Florin-Natkin model. This paper discusses with Molly SPN model. Its definition is as following:

Def 1: Six tuples SPN =(S, T, F, W, M_0, λ), is a stochastic Petri net system:

1) *(S, T, F, W, M_0) is a P/T system, in which S = {s1, s2,..., sn} is the collection of places.*
2) *$T = \{t_1, t_2... t_m\}$ is the collection of transitions.*
3) *$F \subseteq \{T \times P\} \cup \{P \times T\}$ is the transfer function.*
4) *$W: F \rightarrow N+$ is right function.*
5) *$M_0: S \rightarrow N$ is the initial mark.*
6) *$\lambda = (\lambda_1, \lambda_2, ... \lambda_n)$ is the group of process speed of transitions.*

2.2 Extended Stochastic Petri Net

From Def 1, Stochastic Petri Net model may face these following defects: (1) Space Explosion problem; (2) Not easy to depict dynamic paralleled mechanics. To overcome these defects, we can add object-oriented features and color mechanic on the basic of SPN to get Extended Stochastic Petri Net.

Def 2: Five tuples XSPN= (PNS , Res , Pri, M_0 , λ) is an extended stochastic Petri net system::

7) *In the Petri Nets system,*
   PNS = {PS_1,. PS_2, PS_3, .. , PS_n , }

Which PS_i is a sub-network system and PS_i= (P_i , S_i , IP , OP, T , F, C)

P_i is the normal place and S_i represent the channel, which can keep different kinds of transitions;

IP represents the input interface while OP is the output interface. In this system $IP \cap OP = \Phi$;

T is the transition and we have T = {T_1, T_2,..., T_n}, here Ti =$DLT \cup IST$, $DLT \cap IST = \Phi$. DLT is the delay transition while IST is the instantaneous one; $F \subseteq \{T \times P\} \cup \{P \times T\}$ is the transfer function; C is the color function and we have $C(S_i)$ =Res ;

8) *Res represents the system resource including people and machines;*
9) *P_i is the priority of the network system;*
10) *M_0, λ have the same meaning with traditional stochastic Petri net.*

3. Workflow process modeling based on stochastic petri net.

3.1 A Stochastic Petri Net model for queuing system.

Traditional mathematics methods have inadequate capacity to depict queuing system. If the objective system has following situations such as synchronization, Blocking and Customer Splitting, they can not be solved directly, but need to be transferred to Markov chain. This character is very similar with the Stochastic Petri Net while Stochastic Petri Net is better at describing. So this paper uses Stochastic Petri Net to depict queuing system. By adding queuing theory to Stochastic Petri net, this model becomes clearer to describe queuing system and is easier to analyze and solve.

11) a first in first out system

Fig 1 is a document review example. Documents arrive at a certain department on the speed λ and then come into service queue (use normal place p_1 to represent it). System judges that whether this department currently is free or not and whether this department still has resources. If this system is free with usable resources, documents will be reviewed by the service rate μ and will release the resources when the process is finished. If there exist no resources, documents will wait until resources release.

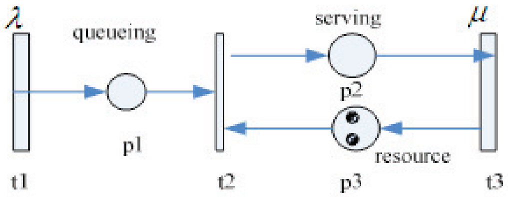


Figure 1. A FIFO queuing model based on stochastic Petri Net

12) Queuing model with priorities

As Fig 2, documents with priorities arrive at the certain department with speed λ and then join in the corresponding waiting queue (represented by p_{1n}). System will make the judge that whether this department has free roles available which also means that whether there are any free resources. If yes, transition t_2 will check the documents from ones with higher priority to the lower ones in a service rate μ. When finished, the resources will be released; if no, documents will wait utile resources released.

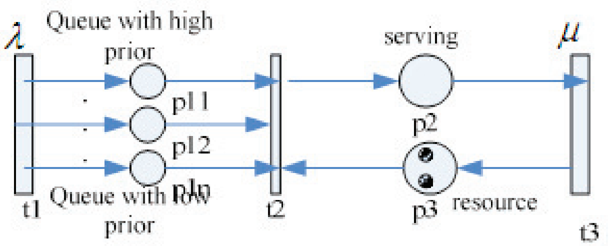
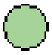
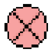
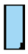


Figure 2. Petri net model for a queuing system with priorities

3.2 An example of workflow process modeling based on stochastic Petri net

This paper actualized the documents processing system based on a programming method and a hierarchical modeling tool of a simulation environment named Exspect(http://www.exspect.com). As shown in Fig 3, this system can not only clearly describe concurrency workflow with priorities, but also overcome the defects of SPN and improve the data collection ability. The simulation results show that this workflow system can run with better performances.

In this figure,  is the channel which acts the same with the place in traditional Petri net;  is the store which can save tokens with different colors;  is the process, the same as the transitions in traditional Petri net, while this kind of transitions often has time delay;  is the instantaneous transition which has not time delay. 

is the time trigger providing system clock; 

is the random number trigger. Functions of different elements are revealed on Tab 1.

4. The System Implementation Of The Major Part In The Model

4.1 the engender of the initial documents

We use Random and Time tools to stochastically produce documents information with priorities. When Random>=0.6, system will produce the request documents for new product developing. When Random<0.6, system will produce the request documents for old product renewing. And at the same time, if Random>=0.3, request documents with high priority will be produced; verse vice, low priority will be produced. The time tool provides the initial time data for documents. For example, the sentence for requesting documents of new products developing is:

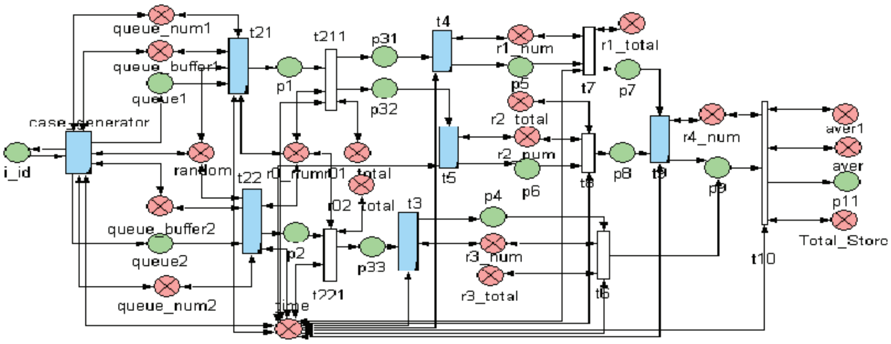


Figure 3. process model based on Exspect

TABLE I. Function Description Of Objects In Role-Tasks System

Caption	Function
i_id	To produce tab continuously (1,2,…,n)
case_generator	Produce tasks with two priorities and send to corresponding place
queue_num1(queue_num 2)	To save the number of documents of new product developing(old product renewing)
queue_buffer1(queue_buffer2)	To save the information of the documents of new product developing(old product renewing)
queue1(queue2)	
t21(t22)	Save the information of the documents in processing
P1(P31,P32, P5, P6, P7, P8,p9)	Role a fetch and deliver higher priority documents from the queue
P2(P33,p4)	Channel for new product developing documents
t211(t221,t6,t7,t8,t10)	Channel for old product renewing documents
r0_num(r1_num, r2_num, r3_num,	Instantaneous processing transitions
r4_num)	To save the number of resources of role a (b, c, d)
r01_total(r1_total, r2_total, r4_total)	To save the total time and pieces of new products developing documents processed by role a (b, c, d)
r02_total(r3_total,)	
Total_store	To save the total time and pieces of old products renewing documents processed by role a (e)
aver(aver1)	
	To save the total time and pieces of documents
	To save the total time and pieces of new products developing (old products renewing) documents processed

i_id <- i_id+1 ,

if random >=0.7 then

queue_buffer1 <- [id:i_id, cid:1, i_time:time, s_time:time, f_time:time, e_time:time, pid:'h'] ins

queue_buffer1

else

queue_buffer1 <- [id:i_id, cid:1, i_time:time, s_time:time, f_time:time, e_time:time,pid:'l'] ins queue_buffer1

fi,

queue_num1 <- queue_num1+1 ,

queue1<- queue_num1 delay poisson (0.2,0.5)

For multi-hierarchies of priorities, new embranchments can be added into the above IF chooses.

The only difference is to revise the tab of these priorities. For example, we can add middle (m) to the system besides high (h) and low (l).

4.2 The actualization of queuing system with priorities

The model in Fig 5 has queuing ability which can give collaborative process for the paralleled work of multi-tasks. When tasks arrive at system, they will be allocated to corresponding queues queue_buffer1 (queue_buffer2) by their types and priorities. Role a will choose the task with long waiting time and highest priority to process. This keeps the task with earliest initial time to be put on the front of the queue. When getting out of the queue, according to the rule, system will first refer to the high priority tasks. If there are, these tasks will be pulled out of the queue firstly. As the minimum number (that is the earliest initial time) matches exactly with the records comply with the conditions (high priority), earliest entering tasks with high priorities will be firstly out of the waiting queue; if there are not, earliest entering tasks with less higher priorities will be pulled out. The major program of queuing in and out is as following:

if 'h' elt rng([x:queue_buffer1|x@pid])

then

p1<-pick(set([x:queue_buffer1|x@pid='h']))delay nexp(15.0,0.5),

queue_buffer1<- set([x:queue_buffer1|x@id!=(pick(set([y:queue_buffer1|y@pid='h']))@id)])

else

p1<-pick(set([x:queue_buffer1|x@pid='l']))delay nexp(15.0,0.5),

queue_buffer1<- set([x:queue_buffer1|x@id!=pick(set([y:queue_buffer1|y@pid='l']))@id])

fi

4.3 The imletation of basic statistics

A major function of this model is to give statistics for the process time of different roles so that it is easy for system capability analysis.

aver<- [sid:aver@sid+1,totaltime:aver@totaltime+p10@e_time-p10@i_time], This sentence is to calculate for the total work time for processing all the new product developing documents. And other sentences used for statistics are similar with this and we will not repeat this.

5. Conclusions

We use an instance to explain how to implement workflow process with Exspect. The result shows that this modeling method is better than some traditional modeling methods.

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